Remarks

Status and Disposition of Claims

Claims 1-11, 13, and 14 were pending and under consideration with the Final Office Action.

With this amendment, claims 1, 4, 5, and 8 are amended, and claims 2, 3, 6, 7, 12, and 15-24 are canceled. Thus, claims 1, 4, 5, 8-11, 13, and 14 are pending and under consideration with this amendment.

The amendment to claim 1 to recite a specific rate of temperature reduction finds support in, for example, paragraph [0066] of the specification.

Drawings

Applicants respectfully request that the Examiner formally indicate that the drawings are acceptable.

Claim Rejections – 35 U.S.C. §§ 102(a) and 103

The Action maintains the rejection of claims 1, 2, 4, 10, and 11 under 35 U.S.C. § 102(a) over Nobuhiro et al. (JP 2003-218037). The Action also maintains the rejection of claims 3, 5, 6, 7, 13, and 14 under 35 U.S.C. 103(a) as being unpatentable over Nobuhiro et al.

Initially, Applicants respectfully note that the Action does not indicate whether the rejection is being made over an English language abstract or over an English language translation of the entire Nobuhiro et al. document. Applicants respectfully request clarification of the record so that it is clear what document the Examiner has considered. For purposes of responding to the rejection, Applicants have obtained a machine English

language translation and refer to that machine English language translation herein. A copy is attached.

Regarding claim 1, Nobuhiro et al. discloses in claim 6 and at paragraph [0036] that a temperature for forming epitaxial films (5, 6) after forming a first epitaxial film (4) is equal or not more than a temperature for forming the first epitaxial film (4). Also, Nobuhiro et al. discloses at paragraph [0035] that the second epitaxial growth for filling the trench is carried out at 860°C and then the third epitaxial growth is carried out at 840°C. Accordingly, Nobuhiro teaches that an epitaxial layer is grown in a trench of a semiconductor wafer having a trench structure by reducing the temperature from a first fixed temperature to a second fixed temperature. Applicants respectfully submit that Nobuhiro does not anticipate claim 1 and those claims depending therefrom, including claims 4, 10, and 11 (claim 2 has been canceled), which further require, at least, lowering the temperature at a rate of 1 to 100°C/min. Applicants further respectfully submit that at least this feature is not taught or suggested by Nobuhiro et al., and thus, the obviousness rejection over Nobuhiro et al. should be withdrawn.

The Action also rejects claims 8 and 9 under 35 U.S.C. 103(a) as being unpatentable over Nobuhiro et al. JP 2003-218037 in view of Yamauchi et al. (U.S. Patent No. 6,495,294). Applicants respectfully disagree with the rejections for the reasons that follow.

Applicants respectfully submit that the cited art does not teach or suggest an epitaxial layer grown in a trench of a semiconductor wafer having a trench structure by gradually reducing a temperature in a temperature range of 400 to 1150° and then lowering the temperature at a rate of 1 to 100°C/min. The Action asserts on page 9, lines 2-3, that lowering the temperature at a rate of 1 to 100°C/min is obvious "without showing that the claimed ranges achieve unexpected results relative to the prior art range." In response to this point, Applicants respectfully note that the claimed features characteristics that are surprisingly better than those of the prior art, specifically with

respect to the dopant profile (see paragraphs [0061] and [0065] of the published specification) of the products produced according to the claimed method.

It is not believed that any additional fees are due with this Amendment. However, any additional fees should be charged to, or any overpayment in fees should be credited to Deposit Account No. 19-0089 (P35795).

Respectfully Submitted,
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Attachment: Machine English language translation of
JP 2003-218037

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* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to the substrate processing technology for semiconductor device formation.
[0002]
[Description of the Prior Art]When performing trench embedded EPI growth, the growth rate in the side changes with trench depth. Since the growth rate is large, before a trench-bottoms part is buried as a result, an opening is closed and, specifically, embedded [poor] occurs inside a trench, so that it is close to a trench opening. It is proposed like embedded epitaxial growth Takumi who performs the solvent wiping removal of the opening by HCl etching in JP,2001-196573,A as a means to control generating embedded [such poor].
[0003]This art is explained. As are shown in drawing 10 (a), and the trench 101 is formed in the semiconductor substrate 100 and it is shown in drawing 10 (b), As the epitaxial film 102 is formed on the semiconductor substrate 100 which includes the inside of the trench 101 with an epitaxial grown method and it is further shown in drawing 10 (c), In the atmosphere having contained halogenides, such as hydrogen chloride, some epitaxial films 102 are etched using a gas-phase-etching operation of halogenides, such as hydrogen chloride, to the epitaxial film 102. In particular, in the HCl etching process under decompression, the solvent wiping removal of an opening is performed using the feature whose selective etching of the opening of the trench 101 becomes possible by etching on hotter supply rate-limiting conditions. Thereby, the angle (tapered angle) theta made on a trench-bottoms side and the side can be made smaller. And as shown in drawing 11 (a), it embeds with the epitaxial film 102,103 on which the epitaxial film 103 was again formed on the semiconductor substrate 100 which includes the inside of the trench 101 with an epitaxial grown method, and the inside of the trench 101 was put. It can carry out like drawing 11 (b) by performing annealing under a hydrogen atmosphere in order to lose embedded [slit shape / poor].
[0004]However, a limit is among tapered angle theta obtained by control of only etching temperature or time, so that an embedded trench becomes a high aspect, and embedded [poor] may remain in a trench as a result.
[0005]Therefore, in the embedded EPI stage film formation which added the conventional HCl etching process, HCl etching technology whose embedded disposition top becomes more possible is desired.
[0006]
[Problem(s) to be Solved by the Invention]This invention is made under such a background and the purpose is to provide the manufacturing method of the semiconductor substrate it becomes possible whose to raise embedded nature more in embedded EPI stage film formation.
[0007]
[Means for Solving the Problem]After according to the invention according to claim 1 forming a

trench in a semiconductor substrate and forming an epitaxial film on a semiconductor substrate which includes inside of a trench with an epitaxial grown method, In atmosphere having contained a halogenide, etch some epitaxial films using a gas-phase-etching operation by a halogenide under atmosphere more than process pressure in the case of formation of an epitaxial film, and it sets after that, In embedded EPI stage film formation, embedded nature improves more by embedding with an epitaxial film on which an epitaxial film was again formed on a semiconductor substrate which includes inside of a trench with an epitaxial grown method, and inside of a trench was put.
[0008]After according to the invention according to claim 2 forming a trench in a semiconductor substrate and forming an epitaxial film on a semiconductor substrate which includes inside of a trench with an epitaxial grown method, Some etching processes of an epitaxial film using a gas-phase-etching operation according [on atmosphere having contained a halogenide and] to a halogenide in the bottom of atmosphere more than process pressure in the case of formation of an epitaxial film, By embedding with an epitaxial film on which inside of a trench was put, embedded nature of a multiple-times line improves membrane formation processing of an epitaxial film more in embedded EPI stage film formation.
[0009]It may be made to add here the process according to claim 3 of performing more round processing of a corner in an epitaxial film in a trench by heat treatment after some etching processes of an epitaxial film like.
[0010]To Claim 4, like a description with the bottom of atmosphere more than process pressure in the case of formation of an epitaxial film in some etching processes of an epitaxial film. It supposes that it is below ordinary pressure, or is good for Claim 5 like a description in the bottom of atmosphere more than process pressure in the case of formation of an epitaxial film in some etching processes of an epitaxial film being the range of 80 - 600torr.
[0011]It becomes that forming temperature of the epitaxial film according to claim 6 formed after opposite Perilla frutescens (L.) Britton var. crispa (Thunb.) Decne. like at forming temperature of the first epitaxial film is equivalent, or is less than it with a practically desirable thing.
[0012]Not less than 800 ** becomes the thing according to claim 8 which was [like] excellent in the embedded nature of an EPI film when forming temperature of the last epitaxial film was made into the range of 830-850 ** especially about forming temperature of the last epitaxial film like a description at Claim 7.
[0013][before forming an epitaxial film after / according to claim 9 / forming a trench in a semiconductor substrate like], If a film which has a tensile stress to a substrate is formed in a field opposite to a field in which a trench in a semiconductor substrate was formed, a substrate can be curved, a trench opening can be extended and it will become the thing excellent in the embedded nature of an EPI film.
[0014]Specifically, it is good to use a silicon nitride film as the film according to claim 10 which has a tensile stress to a substrate like using a silicon substrate as a semiconductor substrate.
[0015]
[Embodiment of the Invention](A 1st embodiment) The embodiment which materialized this invention is hereafter described according to Drawings.
[0016]The manufacturing method in this embodiment is explained using drawing 1, and 2 and 3. Drawing 1 and 2 sketch the section SEM image in each manufacturing process. Drawing 3 is a profile about the treatment temperature and process pressure in the case of epitaxial growth and gas phase etching.
[0017]First, as shown in drawing 1 (a), the silicon substrate 1 is prepared, the silicon oxide 2 is formed in the whole surface at the upper surface, and the oxide film 2 concerned of the part used as a trench formation region is removed. And this oxide film 2 is used as a mask, the silicon substrate 1 is etched, and the trench 3 is formed. What laminated the nitride or the oxide film, and the nitride may be used instead of the oxide film 2 as a mask. Trench etching uses dry etching or the wet etching of anisotropy.

[0018]After that, washing for removal of a resultant and the oxide film 2 used as a mask is performed. As shown in drawing 1 (b), the epitaxial film 4 is formed on the silicon substrate 1 which includes the inside of the trench 3 with an epitaxial grown method. Epitaxial growth using LP gas-CVD system is performed in more detail. Like drawing 3, (embedded EPI membrane formation in a figure) and growing temperature shall be 860 **, and growing pressure is set to 80torr.
[0019]It may be made to perform flattening processing of a trench wall by heat-treating before EPI film membrane formation in the decompressed atmosphere of a non-oxidizing quality and un-nitriding nature gas. Then, as shown in drawing 1 (c), in the atmosphere having contained hydrogen chloride (HCl), some etching processes of the epitaxial film 4 using a gas-phase-etching operation of hydrogen chloride are performed. At this time, it carries out the bottom of the atmosphere more than the process pressure in the case of formation of the epitaxial film 4, and some etching processes of the epitaxial film 4 using a gas-phase-etching operation of hydrogen chloride are performed under these conditions. An etching process is performed by introducing etching gas into the decompressed atmosphere (specifically hydrogen atmosphere) of a non-oxidizing quality and un-nitriding nature gas.
[0020]This process is explained in more detail. Let devices be EPI membrane formation processing and continuous processing using LP gas-CVD system (it processes continuously within the same vacuum devices). (HCl etching in a figure) and temperature are 1150 ** like drawing 3. Like drawing 3, pressures are 600torr and are set to 80 or more torr of EPI forming pressure.
[0021]Thus, the difference of an opening and a pars basilaris ossis occipitalis increases by the rise (formation of a flood matter partial pressure) of process pressure about the processing EPI thickness after HCl etching as working shape within the trench 3 by etching. In the opening of the trench 3, and a center section, forward tapered shape-ization becomes remarkable by the rise (formation of a flood matter partial pressure) of process pressure.
[0022]Then, as shown in drawing 2 (a), the epitaxial film 5 is continuously formed again within the same vacuum devices on the silicon substrate 1 which includes the inside of the trench 3 with an epitaxial grown method. At this time, like drawing 3, (re-embedded EPI membrane formation in a figure) and forming temperature shall be 860 **, and forming pressure is set to 80torr.
[0023]And as shown in drawing 2 (b), in the atmosphere which contained hydrogen chloride continuously within the same vacuum devices, some etching processes of the epitaxial films 4 and 5 using a gas-phase-etching operation of hydrogen chloride are performed. Also at this time, it is made to be the same as that of last time the bottom of the atmosphere more than the epitaxial film 4 and the process pressure in the case of formation of five, and some etching processes of the epitaxial films 4 and 5 using a gas-phase-etching operation of hydrogen chloride are performed under these conditions.
[0024]At this time, the pressure at the time of some etching processes of the epitaxial film by this hydrogen chloride gas is made small compared with the pressure at the time of some etching processes of the epitaxial film by the first hydrogen chloride gas (600torr). That is, like drawing 3, first etching (HCl etching in a figure) is performed by 600torr, and a two-times eye is etched by 80torr (re-HCl etching in a figure). Treatment temperature (re-HCl etching) shall be 1150 ** like last time.
[0025]Then, as shown in drawing 2 (c), the epitaxial film 6 is continuously formed again within the same vacuum devices on the silicon substrate 1 which includes the inside of the trench 3 with an epitaxial grown method. At this time, like drawing 3, (third-time embedded EPI membrane formation in a figure) and forming temperature shall be 840 **, and the pressure is set to 80torr. The inside of the trench 3 is embedded with the piled-up epitaxial films 4, 5, and 6 by membrane formation of this epitaxial film of a series of. Each epitaxial films 4, 5, and 6 introduce dopant gas required at the time of membrane formation that it should consider as the target conductivity type.
[0026]Thus, forward tapered shape-ization becomes remarkable by repeating EPI membrane formation and HCl etching as working shape in the trench 3. Then, flattening of the surface of the

epitaxial films 4, 5, and 6 on the silicon substrate 1 is carried out. this -- anisotropy grinding treatment [or], etchback, or wet etching -- or it carries out by seeing two or more sets.
[0027]In the semiconductor substrate formed by making it such, it is got blocked and is checking that embedded [, such as "**", / poor] is decreasing in a trench after the flattening polish carried out to the embedded backward one.
[0028]Hereafter, since various kinds of experiments were conducted, it is explained. This invention persons conducted various kinds of experiments on the HCl etching process in drawing 10 and the art explained using 11, and obtained the following results. Drawing 4 showed the result of having measured the generation state etching time and embedded [poor], took tapered angle theta and etching time along the horizontal axis, and has taken length L (refer to drawing 11 (a)) slit shape embedded [poor] along the vertical axis. Since it reduces, size L embedded [poor] formed in a trench from this drawing 4, so that etching time is long is understood that it is effective in reduction embedded [poor] to make tapered angle theta small (forward-tapered-shape-ize).
[0029]Drawing 5 (a) is the section SEM image after performing HCl etching by 80torr, and drawing 5 (b) is the section SCN image after embedding the inside of a trench by re-EPI membrane formation after that. Drawing 6 (a) is the section SEM image after performing HCl etching by 600torr, and drawing 6 (b) is the section SEM image after embedding the inside of a trench by re-EPI membrane formation after that. While tapered angle theta of the trench side became small in the direction which performs HCl etching by 600torr from this drawing 5 and 6 compared with the case where HCl etching is performed by 80torr, it turned out that length L of a slit shape embedded faulty point becomes short. That is, it is effective to raise process pressure and to perform HCl etching as a taper-rolling method in a HCl etching process (with flood matter partial pressure).
[0030]As for this, the average free process of HCl gas decreases by the rise (flood matter partial pressure) of process pressure, the etching quantity in the deep portion of a trench decreases, and, on the other hand, it is presumed that the etching quantity in a trench opening is almost equivalent, therefore it is for forward tapered shape-ization to progress as a result.
[0031]Therefore, since it can be coped with only by processing condition change compared with drawing 10 and the process explained using 11, performing HCl etching by 600torr like this embodiment has adding processing and an unnecessary additional apparatus. For the processing (processing with a flood matter partial pressure) in which process pressure rises [make], movement of the silicon atom in the corner part (corner) in a trench is large, and more round processing of a corner progresses. As a result, control of a crystal defect and relaxation of stress concentration are attained.
[0032]furthermore -- as a taper-rolling method [in / at this embodiment / a HCl etching process] -- the rise (flood matter partial pressure) of process pressure -- in addition, it is made to perform HCl etching of multiple times. In detail, by repeating HCl etching and EPI membrane formation two or more times, forward tapered shape-ization progresses about the side in a trench and embedded [poor] is reduced as a result (the effect of forward-tapered-shape-izing becomes large, and embedded nature improves). Since it is only processing condition change compared with the process explained also in this case using drawing 10 and 11, an additional apparatus is unnecessary.
[0033]At this time, it compares with the pressure at the time of some etching processes of the epitaxial film by the first hydrogen chloride gas (600torr) like drawing 3, The pressure at the time of some etching processes of the epitaxial film by the hydrogen chloride gas in it or subsequent ones is made small (80torr), and this effect is explained using drawing 7.
[0034]It is a case where drawing 7 (a) performed etching which is the first time by 600torr, and also performs etching of a two-times eye by 600torr, and is a case where performed etching whose drawing 7 (b) is the first time by 600torr, and etching of a two-times eye is performed by 80torr. Only the EPI film in a trench opening is etched in drawing 7 (a), and the EPI film of the middle height part of a trench is not etched, but, [in / whole / a trench],is [forward-tapered-shape-] hard to beized. On the other hand, in drawing 7 (b), in the opening of a trench, and a middle height part, an

EPI film is etched and the whole inside of a trench becomes forward tapered shape shape.
[0035]We decided to perform 2nd EPI growth (re-embedded EPI membrane formation of drawing 3) for trench embedding at 860 **, and decided to perform 3rd EPI growth (third-time embedded EPI membrane formation of drawing 3) at 840 **. This is based on the following experimental results. The relation between epitaxial growing temperature and length L (refer to drawing 11 (a)) of a slit shape embedded faulty point is shown in drawing 8. That is, epitaxial growing temperature was taken along the horizontal axis, and length L of the slit shape embedded faulty point is taken along the vertical axis. This figure shows that embedding nature improves because epitaxial growing temperature shall be 840 ** (low temperature). Below 840 **, crystallinity worsens and it is easy to generate poor embedding by the joined part of the growth from a trench side attachment wall. Like drawing 3, the 1st embedded EPI membrane formation considers it as 860 **, and is thinking crystallinity as important.
[0036]This embodiment has the following feature like the above.
(**) As are shown in drawing 1 (a) and it is indicated in drawing 1 (b) as the process of forming the trench 3 in the silicon substrate 1, As it is indicated in drawing 1 (c) and drawing 2 (a), (b), and (c) as the process of forming the epitaxial film 4 on the silicon substrate 1 which includes the inside of the trench 3 with an epitaxial grown method, Some etching processes of the epitaxial film in the bottom of the atmosphere more than the process pressure in the case of formation of the epitaxial film 4 using the gas-phase-etching operation of hydrogen chloride on the atmosphere having contained hydrogen chloride, It has the process embedded with the epitaxial films 4, 5, and 6 to which the multiple-times line repeated membrane formation processing of an epitaxial film (5, 6) for the inside of the trench 3, and the process of carrying out flattening of the surface of the epitaxial films 4, 5, and 6 on the silicon substrate 1. Therefore, in embedded EPI stage film formation, embedded nature improves more.
(**) The bottom of the atmosphere more than the process pressure in the case of formation of the epitaxial film in some etching processes of an epitaxial film, Below ordinary pressure carried out, it was good to have considered it as the range of 80 - 600torr especially, and 600torr and 2nd etching were set to 80torr for the 1st etching in this embodiment.
(**) The forming temperature of the epitaxial films 5 and 6 formed after opposite Perilla frutescens (L.) Britton var. crispa (Thunb.) Decne. at the forming temperature of the first epitaxial film 4 is good equivalent or to make it less than it, and may be 840 ** by 860 ** and the 3rd EPI film 6 with 860 ** and the 2nd EPI film 5 by the 1st EPI film 4 by this embodiment. The forming temperature of the last epitaxial film 6 shall be not less than 800 **, it is good to consider it as the range of 830-850 ** especially, and in this embodiment, it will be considered as 840 **, and if it does in this way, it will become the thing excellent in the embedded nature of an EPI film.
[0037]Hereafter, example of another over the embodiment described so far is explained. After etching the EPI film by hydrogen chloride gas, the heat treatment process under a hydrogen atmosphere is added, the corner of the EPI film within the trench 3 is rounded off and processed, and it may be made to enlarge the effective area product in a trench opening. More specifically a device is made into EPI membrane formation processing and continuous processing using LP gas-CVD system, temperature is 1150 **, for example, and a pressure is 80 - 600torr (they may be 80 or more torr of EPI forming pressure). Thus, more round processing of a trench opening and a pars basilaris ossis occipitalis is performed, and it may forward-tapered-shape-be made toize the inside of a trench by repeating etching by hydrogen chloride gas, and hydrogen annealing more.
[0038]It will become more desirable, if EPI stage film formation, the partial etching process of an EPI film, the more round process of the EPI film corner in a trench, and EPI film re-stage film formation are continuously processed within the same vacuum devices when adding this processing and performing it. The process of rounding off and processing the corner of the EPI film within the trench 3 is good to heat-treat in the decompressed atmosphere of a non-oxidizing quality and un-nitriding nature. For example, hydrogen or rare gas is used. About temperature, it is considered as

an elevated temperature rather than EPI forming temperature, and it is good to consider [not less than 900 **] it as not less than 1100 ** preferably. A degree of vacuum is larger than the time of EPI membrane formation, and is more preferably set to 300 or more torr 10 or more torr.
[0039]In said (**), as shown in drawing 1 (b), (c), and drawing 2 (a), (b), and (c), Some etching processes of the epitaxial film in the bottom of the atmosphere more than the process pressure in the case of formation of the epitaxial film 4 using the gas-phase-etching operation of hydrogen chloride on the atmosphere having contained hydrogen chloride, Although the multiple-times line made membrane formation processing of an epitaxial film (5, 6) the process embedded with the epitaxial films 4, 5, and 6 on which the inside of the trench 3 was put, instead of this, the inside of a trench may also be embedded by one etching and one subsequent EPI growth. That is, the process of etching some epitaxial films 4 in the atmosphere having contained hydrogen chloride using a gas-phase-etching operation of hydrogen chloride under the atmosphere more than the process pressure in the case of formation of the epitaxial film 4, It is good also as a thing provided with the process embedded with the epitaxial films 4 and 5 on which the epitaxial film 5 was again formed on the silicon substrate 1 which includes the inside of the trench 3 with an epitaxial grown method, and the inside of the trench 3 was put.
[0040]As other techniques, as shown in drawing 9, it may be made like. First, as shown in drawing 9 (a), the wafer form silicon substrate 10 is prepared, and the trench 11 is formed in the main table side (upper surface) of the wafer-like silicon substrate 10 as shown in drawing 9 (b). And as shown in drawing 9 (c), the silicon nitride film 12 is formed in the whole surface to the rear face (undersurface) of the wafer-like silicon substrate 10. This silicon nitride film 12 has a tensile stress to the silicon substrate 10, and, thereby, the silicon substrate 10 curves in the state where a top serves as a convex in that center section. As a result, the opening of the trench 11 spreads. Then, as shown in drawing 9 (d), the EPI film 13 is formed in the main table side (upper surface) of the wafer-like silicon substrate 10, but since the trench opening has spread by curving the wafer form board 10 then, it excels in the embedded nature of the EPI film, and "**" is hard to be formed. Thus, after forming the EPI film 13 on the substrate 10 including the inside of the trench 11, as said embodiment described, Some EPI films 13 are etched using a HCl etching operation above the process pressure in the case of formation of the EPI film 13, and it embeds by the EPI film on which the EPI film was formed on the substrate 10 including the inside of the trench 11 further again, and the inside of the trench 11 was put. And as shown in drawing 9 (e), the silicon nitride film 12 formed in the rear face of the wafer form board 10 is removed by etching by phosphoric acid. Thereby, curvature is lost. Next, flattening of the surface of the EPI film on the substrate 10 is carried out by polish etc.
[0041]it improves embedded [poor] by heat-treating as a technique of further others in the decompressed atmosphere of a non-oxidizing quality and un-nitriding nature (setting to a hydrogen atmosphere) after re-membrane formation of an EPI film -- it may be made like (it loses). In this case, it will become more desirable if these processings are continuously processed within the same vacuum devices.
[0042]It may be made to etch some epitaxial films 4 using the gas-phase-etching operation by halogenides other than hydrogen chloride in the atmosphere having contained halogenides other than hydrogen chloride under the atmosphere more than the process pressure in the case of formation of the epitaxial film 4.

[Translation done.]